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Archeterokrohnia docrickettsae (Chaetognatha: Phragmophora: Heterokrohniidae), a new species of deep-sea arrow worm from the Gulf of California

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Abstract

A new species of deep-sea chaetognath, *Archeterokrohnia docrickettsae* n. sp. is described from a single specimen captured by the ROV *Doc Ricketts* ~2 m above the sea floor at 3245 m depth in the Pescadero Basin of the Gulf of California, Mexico. This is the first record of a living specimen of *Archeterokrohnia* and the second known occurrence of *Archeterokrohnia* in the Pacific Ocean. In life, the head and trunk sections were orange, while the tail section was translucent, a unique colour pattern not before seen in chaetognaths. Observations of its swimming behaviour *in situ* are given. Comparisons are made with the three other species of *Archeterokrohnia*. At 28.5 mm in length, this is the largest known species of the genus. An artificial key to the four species of *Archeterokrohnia* is presented.

Key words: Gulf of California, chaetognath, deep sea, zooplankton

Introduction

Chaetognaths of the family Heterokrohniidae are known to inhabit deep-sea environments around the globe. Specimens of heterokrohniids are often in poor condition because they have been captured with nets fished to great depths and then preserved with other zooplankton for years before being passed on to a taxonomic expert. Many of these are thought to be benthopelagic (Casanova 1986a) or hyperbenthic (Bieri 1991). Over the last two decades, *in situ* observations of pelagic marine organisms have become more common (Haddock 2004), including *in situ* and behavioural observations of chaetognaths (Haddock & Case 1994; Thuesen *et al.* 2010). During the second leg of a Monterey Bay Aquarium Research Institute (MBARI) research expedition to the Gulf of California in 2012, one very large specimen of a heterokrohniid chaetognath new to science was observed near the sea floor and collected using the ROV *Doc Ricketts*.

Material and methods

Sample collection. Deep-sea organisms were collected on the second leg of MBARI's 2012 Research Expedition to the Gulf of California aboard RV Western Flyer, February 17–26, 2012. While searching for benthopelagic chaetognaths during dive #342 of ROV *Doc Ricketts*, a bright orange-coloured organism was observed swimming ~2 m above the sea floor at 3245 m depth. Although the specimen did not appear like other chaetognaths at first sight, the seminal vesicles were seen clearly, and the specimen was captured in a sealed container using the ROV's 'detritus sampling' system. The ROV returned to the surface ~9 hours following collection, and the specimen was recovered. At the sampling depth, the temperature, salinity and oxygen content were 1.9° C, 34.7 psu and 26.5% saturation, respectively.

Photography. *In situ* digital video was taken with an Insite Pacific Zeus Plus High Definition TV camera attached to ROV *Doc Ricketts*. Immediately upon recovery aboard ship, the specimen was transferred to a

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darkroom photo tank using seawater from the same sample container to maintain its excellent physical condition. Photos of the living specimen were taken with a handheld Nikon D5100 digital camera with attached macro lens. The camera was then attached to a Nikon SMZ-1500 dissecting microscope for more detailed imaging. Within 30 minutes, the specimen started to show signs of deterioration, and it was transferred to 5% formaldehyde in seawater solution for fixation. It took several months for the specimen to make its way from Mexico to the United States, and laboratory observations were made 4–6 months after capture using a Leica MZ16 stereomicroscope with a Syncroscopy high depth-of-field automontage imaging system. Brightness and contrast of some images (Fig. 4) were adjusted in a linear fashion in Photoshop to highlight anatomical features.

Systematic account

Order Phragmophora Tokioka, 1965

Family Heterokrohniidae Casanova, 1985

Genus *Archeterokrohnia* Casanova, 1986

***Archeterokrohnia docrickettsae* n. sp.**
(Figs 1–4)

Etymology. Named for the Monterey Bay Aquarium Research Institute's ROV *Doc Ricketts*, in turn named in honor of marine biologist Ed Ricketts, co-author of *Sea of Cortez* (Steinbeck & Ricketts 1941) and inspiration for the character "Doc" in the novel *Cannery Row* (Steinbeck 1945).

Material examined. *Holotype*: The single specimen of this species is deposited in the Santa Barbara Museum of Natural History (SBMNH)—a mature individual, 28.5 mm total length captured at 3245 m depth, at the north end of Pescadero Basin in the Gulf of California, Mexico (24°22'2.47" N, 109°12'29.44" W), 24 February 2012 (SBMNH No. 235523).

Description. Total body length excluding tail fin (TL) 28.5 mm. Tail section 55.2% of TL. Head blunt when hooded, triangular after preservation, head width 3.5 mm. Hooks 15/15, slender brown, dorsalmost three hooks on each side smaller. Anterior teeth 11/10, with wide bases of uneven sizes. Posterior teeth 4/4, small, about 25% length of anterior teeth, clustered together in front of a plate at posteriormost part of vestibular organ. Vestibular organ located laterally on both sides of anterior teeth, joining together in an extension below posterior teeth and ending in a plate with small denticles. No vestibular papillae observed. Apical organ triangular, protruding from hood while alive. Eyes absent. Corona ciliata horseshoe-shaped. Trunk section of fairly uniform width (4.0 mm); body begins to taper posteriorly at tail/trunk junction. Body with slight ventral bend at tail/trunk junction; trunk section bright orange throughout in life. Anterior part of gut forms red esophagus once preserved; gut ivory-coloured and opaque. Transverse musculature 80% of trunk, 17% of tail. Ventral ganglion beginning at midpoint of trunk section, embedded within alveolar tissue on posterior half of trunk section, robust and elongated. One pair of lateral fins, rayed, starting just anterior of tail/trunk junction extending to the seminal vesicles. Small extension of each lateral fin ending in a ciliary fence, slightly posterior of anus. Ovaries cob-like, with many ova of different sizes. Annex gland present; annex gland diverticulum not observed. The specimen had mated, and each seminal receptacle contained a sperm packet. Seminal vesicles with inner core clearly differentiated from outer section; both parts 'hooked' anteriorly. Tail fin reaching posterior part of seminal vesicles, its form spathulate with 6 prominent ciliary fence organs on both ventral and dorsal sides. Further diagnostic information is given in Table 1.

Remarks. This species is placed in the genus *Archeterokrohnia* on the basis of its extensive transverse musculature (~80% or more of the trunk section), a tail section that is 50% or more of the total body length, transverse musculature present in the tail section, a single lateral fin, and apical head organs. At 28.5 mm in length, *A. docrickettsae* is the largest species in the genus. Comparisons with the other three species of *Archeterokrohnia* are given in Table 1 based on the information summarized in Kapp (1991), following her format. A short artificial key is presented below to readily distinguish the four species of *Archeterokrohnia*.

TABLE 1. Morphological characteristics and distribution information for *Archeterokrohnia docrickettsae* sp. nov. and the three other species belonging to the genus *Archeterokrohnia* modified from the summary of Kapp (1991) with additional information from Casanova (1991).

Characteristic	*A. docrickettsae* sp. nov.	*A. longicaudata* (Hagen & Kapp, 1986)	*A. palpifera* Casanova, 1986	*A. rubra* Casanova, 1986
Total length (TL)	28.5 mm	12.9 mm	7.1 mm	27.0 mm
Tail length	55.2% of TL	56% of TL	54.8% of TL	50–52% of TL
Lateral fins	With rays, beginning slightly above trunk–tail septum. Small adhesive organs on the most anterior part of lateral fins, slightly posterior of the anus.	With few isolated rays, beginning slightly above trunk–tail septum	Completely rayed, beginning at trunk–tail septum	Rayless, beginning slightly more than half–way from trunk–tail septum to the ventral ganglion
Tail fin	Spathulate, with rays, extending up %26 of tail	With few isolated rays, oval, extending up %33 of tail	Rayed, fringe–shaped, extending up %20 of tail	Rayless, extending up ~%35 of tail
Head	Blunt while alive, triangular preserved	Large, broad, triangular	Large, broad, trapezoidal	Large, broad, triangular
Apical gland cell complex	Triangular process extending from head	Present	Slightly developed	Present
Eyes	Absent	Absent	Absent	Absent
Knobs/plates	1 pair of plates located at posteriormost part of vestibular organ.	Absent	1 pair of plates with finely serrated margin replace anterior teeth.	None observed
Anterior teeth	10–11	6–8, conical with broad base	Absent	4–9, conical, bent
Posterior teeth	4, small, clustered together	1, conical	5–6, small, short	2–8, bent, well separated
Hooks	15	17–18, curved, slender, brownish	18	12–15
Vestibular organs	Vestibular organs on both sides of anterior teeth joining together and extending below posterior teeth; no obvious papillae.	Crescent–shaped with small, heterogeneously distributed papillae	Vestigial, 1 pair of palps below with short conical teeth or other structures	2 pairs, anterior one with small papillae, posterior one vestigial
Corona ciliata	Horseshoe shaped	Not observed	Not observed	Outside caliper shaped
Neck canals	Absent	Absent	Not observed	Present
Alveolar tissue	Very dense, integrated with trunk. Not observed after preservation.	Not observed	Not observed	Large
Ventral Ganglion	Elongated and robust, on posterior half of trunk starting at trunk midpoint.	Unknown	Unknown	Small oval at the midpoint of the posterior half of trunk section.
Transverse trunk musculature	~80% of trunk length	~80 % of trunk length	~90 % of trunk length	~80 % of trunk length
Transverse tail musculature	About anterior 17% of tail	About anterior 11.5 % of tail	About anterior 16% of tail	About anterior 13% of tail
Oesophagus	Elongated, brick–red	Elongated, dark orange		Elongated, brick–red
Gut	Ivory–coloured, opaque	Voluminous, grey–yellow		Unpigmented
Ovaries	Cob–shaped, numerous ova of different size	Cob–shaped, numerous ova of different size	Not developed	Not mature
Seminal vesicles	Basis just below lateral fins, triangular, hooked	Elongated epidermal structures	Basis just below lateral fins	Triangular

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TABLE 1. (Continued)

Characteristic	*A. docrickettsae* sp. nov.	*A. longicaudata* (Hagen & Kapp, 1986)	*A. palpifera* Casanova, 1986	*A. rubra* Casanova, 1986
Annex glands	Present with a medial ventral bulb; diverticulum not observed.	Absent?	Not developed	Originating a short distance above the end of the ovaries, with a diverticulum and 2 swellings
Bioluminescent organs	Absent	Not observed	Not observed	Not observed
Type Location	Gulf of California, Mexico	Antarctic Ocean (Atlantic Sector)	Mediterranean Sea off Corsica	Eastern Atlantic Ocean off Mauritania
Number of known specimens	1	1	2 (immature)	6 (+1 Pacific specimen)
Depth range	3245 m	1000–2350 m	2000 m	~4000 m
Depth altitude (meters above bottom)	~2 mab	Unknown	~0 mab	20–100 mab (1–5 mab in Pacific)

Key to the four species of *Archeterokrohnia*

1 Tail section ~50% total length, lateral fins beginning halfway between trunk-tail septum and ventral ganglion, ventral ganglion centered 2/3 distance from head to trunk-tail septum, corona ciliata shaped like an outside caliper, fins rayless . . . . . *A. rubra* Casanova, 1986a

\- Tail section ~55% of total length, lateral fins with rays and beginning at or near trunk-tail septum 2

2 Head trapezoidal, anterior teeth replaced with plates bearing denticles, pair of palps with teeth-like processes located below vestibular organ . . . . . *A. palpifera* Casanova, 1986b

\- Head triangular, both anterior and posterior teeth, well-developed vestibular organs 3

3 Total length 12.9 mm, 6–8 anterior teeth, 1 posterior tooth, no vestibular plates or palps, head with apical gland-cell complex, triangular process on head absent . . . . . *A. longicaudata* (Hagen & Kapp, 1986)

\- Total length 28.5 mm, 10–11 anterior teeth, 4 posterior teeth clustered below a vestibular plate bearing denticles, ventral ganglion slightly posterior to midpoint between head and trunk-tail septum, anterior of head with a triangular process . . . . . *A. docrickettsae* **n. sp.**

Colour. The head and trunk sections were wholly orange in the living specimen, while the tail section was translucent. This unique colour pattern has not been seen previously in a chaetognath. The orange colour of *A. docrickettsae* n. sp. is similar to that of other orange-coloured chaetognaths, such as *Caecosagitta macrocephala* (Fowler) and *Eukrohnia fowleri* Ritter-Zahony (shown in Thuesen *et al.* 2010). Epidermal colour patterns of chaetognaths are known to change rapidly following collection and fade once the specimen is preserved (Bieri *et al.* 1987; Tokioka & Bieri 1966). Over time, even carotenoid gut pigments will fade (Terazaki *et al.* 1977). Our observations on the lack of durability of the colour of *A. docrickettsae* agree with previous observations.

Behaviour. The animal was oriented head down in the water column when first observed. When it started swimming, the specimen was reminiscent of a dime-store goldfish or a pelagic nemertean worm such as *Nectonemertes mirabilis*, rather than a chaetognath. It swam weakly, flexing its body similar to other chaetognaths, but more slowly, then returned to a head-down orientation. It did not display the quick darting escape response of other midwater chaetognaths such as *Caecosagitta macrocephala* and *Eukrohnia fowleri* (Thuesen *et al.* 2010). It made only short, feeble attempts to swim away from the ROV, making it somewhat easy to capture despite its small size and proximity to the sea floor. A video of the capture episode will be available at the MBARI website and on YouTube.

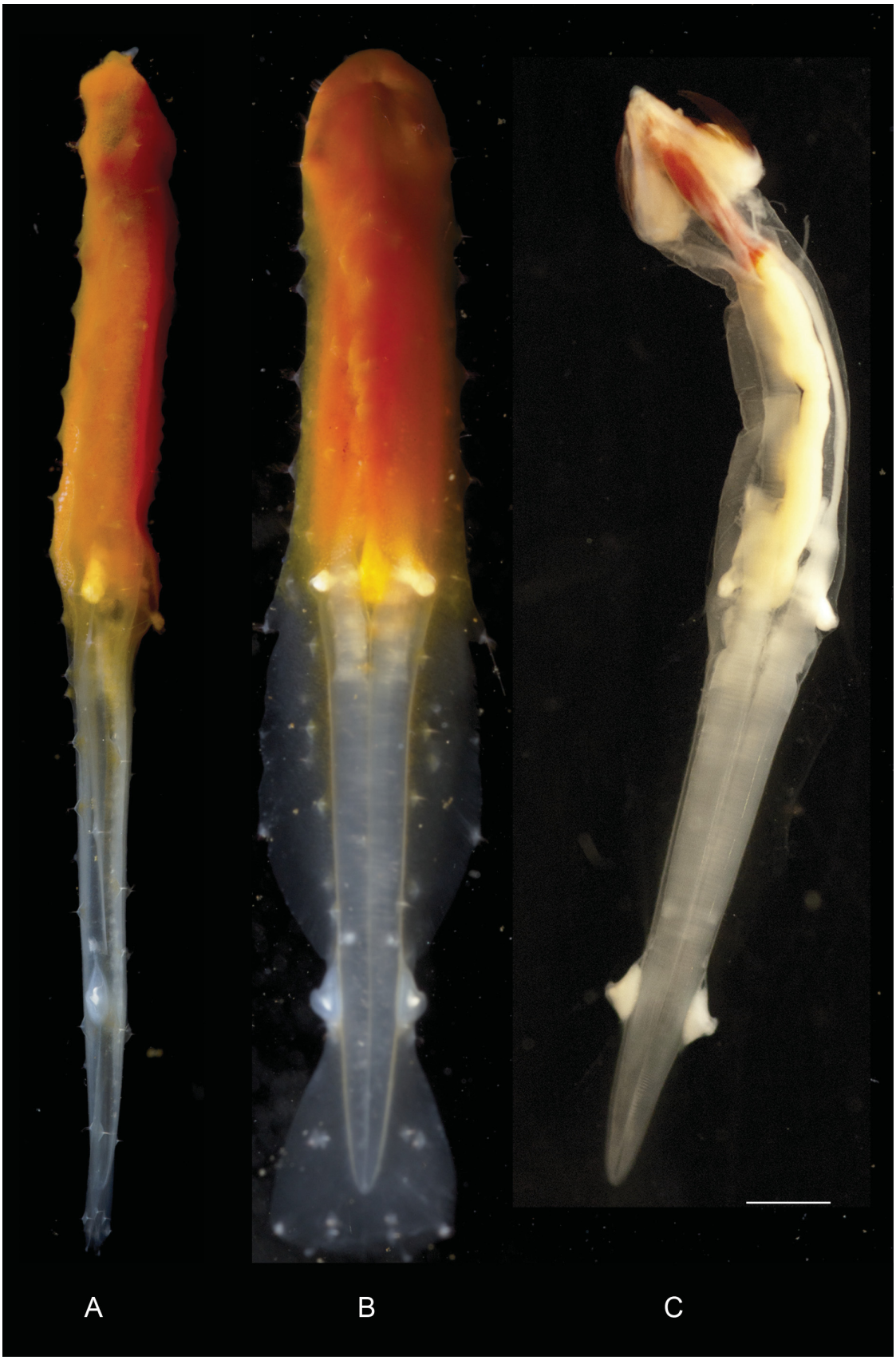

FIGURE 1. *Archeterokrohnia docrickettsae* **n. sp.**, holotype. **A,** lateral view, shortly after recovery aboard ship. **B,** dorsal view, shortly after recovery aboard ship. **C,** dorsal view, after 4 months preservation in 5% formalin/seawater. Total length (not including tail fin) 28.5 mm. Scale bar: 2 mm.

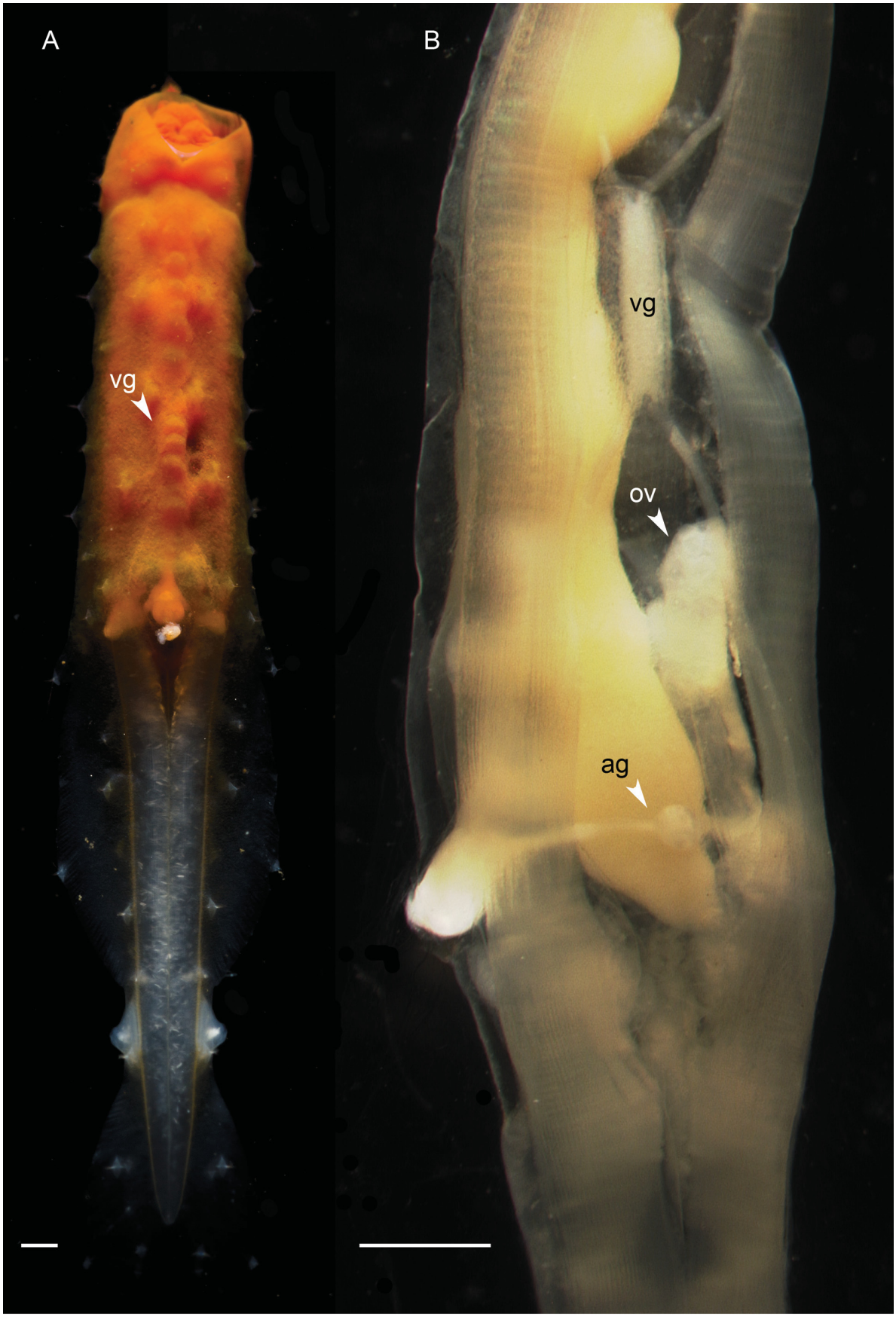

FIGURE 2. *Archeterokrohnia docrickettsae* **n. sp.**, holotype. **A,** ventral view. **B,** ventral ganglion, preserved specimen. Scale bars: 1 mm. Abbreviations: vg, ventral ganglion; ov, ovary; ag, accessory gland.

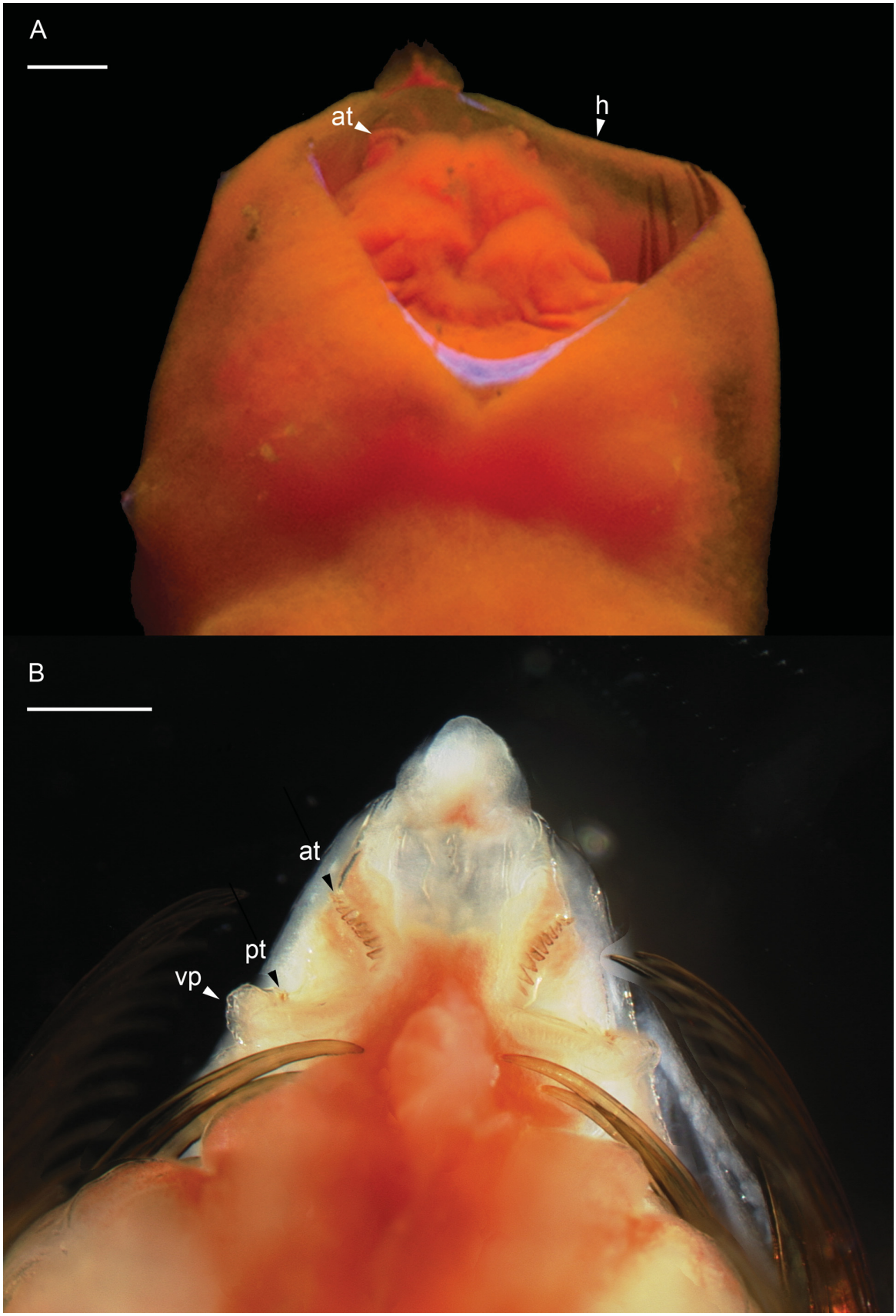

FIGURE 3. Head of *Archeterokrohnia docrickettsae* **n. sp.**, holotype. **A,** ventral view of living specimen with apical gland protruding from beneath the hood. **B,** ventral view of preserved specimen with teeth/hooks. Scale bars: 0.5 mm. Abbreviations: at, anterior teeth; h, edge of hood; pt, posterior teeth; vp, vestibular plate.

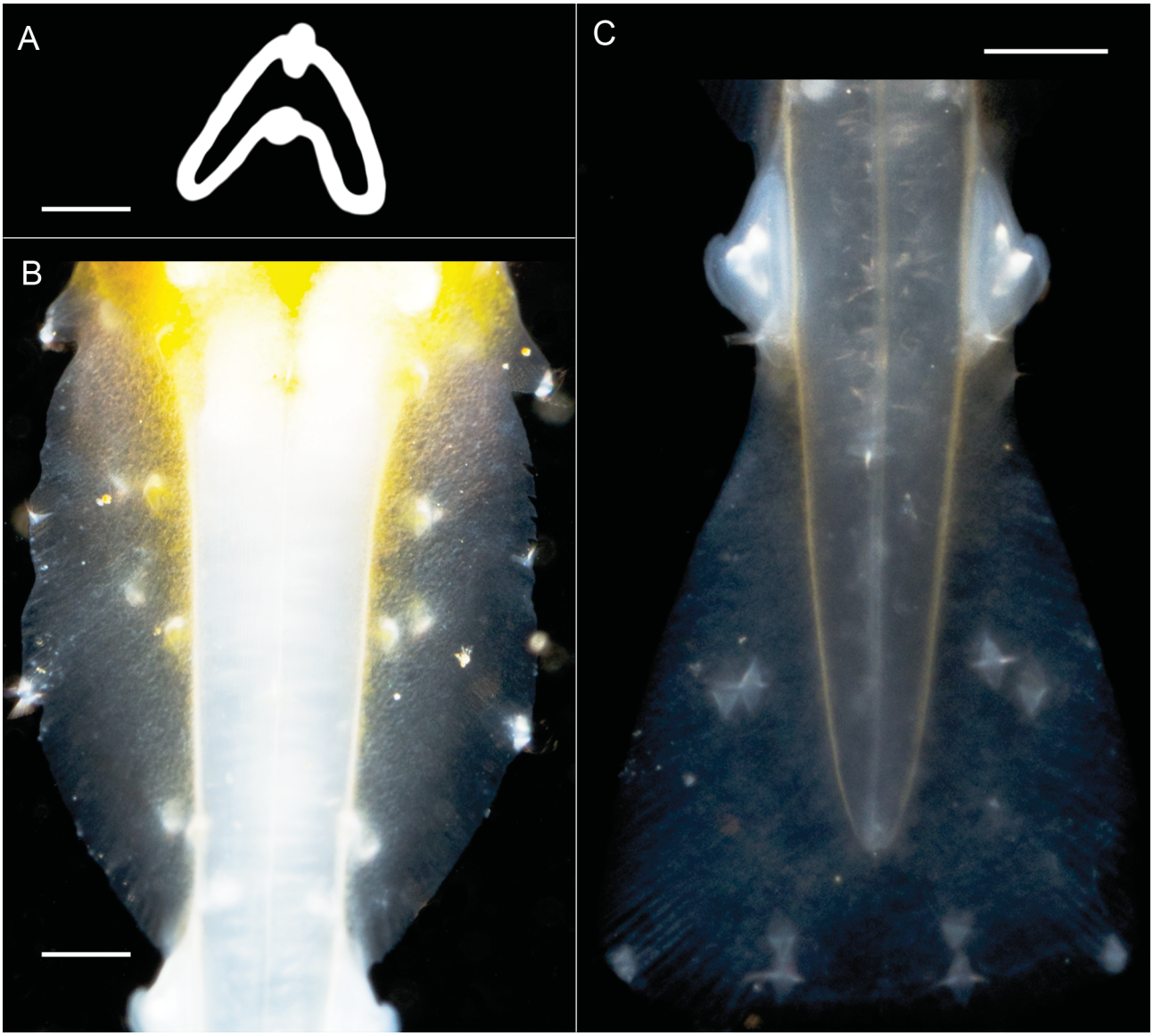

FIGURE 4. *Archeterokrohnia docrickettsae* **n. sp.**, holotype. **A,** trace of corona ciliata. **B,** lateral fins. **C,** seminal vesicles and tail fin. Scale bars: 1 mm.

Discussion

This is the second specimen of *Archeterokrohnia* to be found in the Pacific, as Casanova (1991) reported one specimen of *A. rubra* from the deep-sea flanks of Volcano 7 in the eastern tropical Pacific Ocean that was captured 1–5 m above bottom by a net sampling system on *Alvin*. The current specimen is the only individual belonging to the genus that has been observed while alive. Unsurprisingly, it was observed very near the sea floor. The unique appearance of the animal in life—in both color and overall morphology—is remarkably distinct from its appearance in a preserved state. The general appearance of *A. docrickettsae* in life also distinguishes it from other heterokrohniid chaetognaths that have been observed while alive. These include *Heterokrohnia mirabilis* Ritter-Zahony and *H. murina* Casanova (observed by Thuesen & Childress 1993) and *H. involucrum* Dawson (personal observations). We hypothesize that living specimens of the three other species of *Archeterokrohnia* most likely share an overall body habitus with *A. docrickettsae*, rather than with any of the 16 described species of *Heterokrohnia*. The well-developed transverse musculature in *Archeterokrohnia* spp. probably supports their slow fluctuating swimming patterns in contrast with the typical quick darting movements well known in other chaetognaths. Although Kapp (1991) suggested synonymizing *Archeterokrohnia* with *Heterokrohnia*, Bieri (1991)

included *Archeterokrohnia* in a summary of chaetognath taxonomy and expanded the number of species in the genus to include *A. longicaudata* (Hagen & Kapp 1986). The morphological differences between the two genera, as pointed out by Casanova (1986a,b, 1991) and Casanova & Duvert (2002), and exemplified by the distinctive differences in habitus, are sufficient to warrant maintaining separate generic designation until significant molecular work is undertaken to gain new insights into chaetognath deep phylogeny.

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